Studies on the Vitality of the Japanese Pearl Oyster *Pteria (Pinctada) martensii* (Dunker) under Abnormal Conditions - I. Oxygen Uptake and Shell Movement in Sea Water of Low Oxygen Content

BY

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(5 Text figures)

In recent years, the productivity of the sea water of pearl culture farms has decreased and, from time to time, shown low oxygen content.

In order to obtain further knowledge of the tolerance of oysters for this extreme environmental condition, the effects of low oxygen content of sea water on the rate of oxygen uptake and shell movement of Japanese pearl oysters have been studied and the results are reported in the present paper.

MATERIALS and METHODS

Japanese pearl oysters, *Pteria (Pinctada) martensii* (Dunker), were reared in a pearl farm in Sasebo Bay, Nagasaki Prefecture. The shell length of the oysters was 6.0 to 7.3 cm and the age was 3 years.

Prior to the experiment the oysters were kept in a laboratory tank with running sea water for 2 days. The shells were cleaned to avoid errors due to the respiration of small organisms attached to their surface.

The apparatus used in this investigation, shown in Figures 1 and 2, was a modification of the type used by Hall (1929) for determination of oxygen uptake of fishes at different oxygen contents. One oyster was placed in a metabolism jar containing ca. 1.5 liters of sea water. Temperature fluctuation was kept at a minimum (20° ±1° C) by keeping the jar in a water tank (A), which was supplied by filtered running water. The rate of water flow from the supply tank into the metabolism jar was kept constant (15 liters per hour) in order to avoid the effect of current velocity which was reported by Miyauti & Irie (1965, 1966a). The oxygen content of the water in the jar was controlled by varying the number of *Mytilus edulis* Linnaeus, 1758, in the supply tank and the volume of inflowing water from the storage tank into the supply tank. To avoid the effect of daily rhythm (Mori, 1948a), oxygen uptake was measured once for every one hour period from 10 a. m. to 3 p. m.

In order to observe shell movement, the right valve of the oyster was fastened with alpha cyanoacrylate to a stone sinker placed at the bottom of the metabolism jar. A glass fibre thread attached to the outer margin of the left valve was linked to the lever of a kymograph (Figure 2), placed over the tank (A), and the shell movement was recorded on a weekly kymograph.

Determination of dissolved oxygen was made by the Winkler method. Experiments were carried out during October and November of 1965.

RESULTS

Oxygen Uptake: The rate of oxygen uptake (cc/g dry tissue/hour) was obtained from determinations of the dissolved oxygen in the sea water flowing in and out of the metabolism jar.

The results of tests made on 5 oysters are shown in Table 1 and Figure 3. The rate of oxygen uptake remained nearly constant when the oxygen content of the sea water was maintained above 1.5 cc per liter. Below 1.5 cc of oxygen per liter, the uptake dropped abruptly.

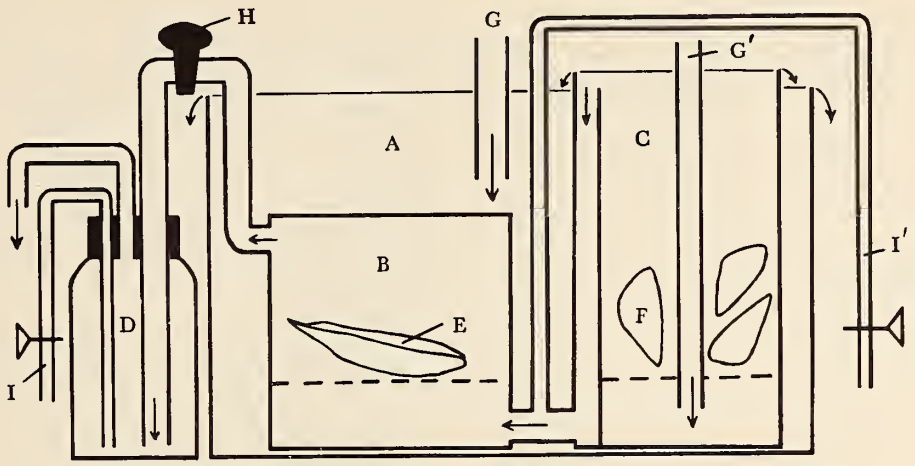

Figure 1

Apparatus used for the determination of oxygen uptake

A: water tank supplied with running sea water; B: metabolism jar; C: supply tank; D: water sample tank; E: pearl oyster; F: *Mytilus edulis*; G, G': supply tube; H: stop cock; I, I': tube for taking samples of water

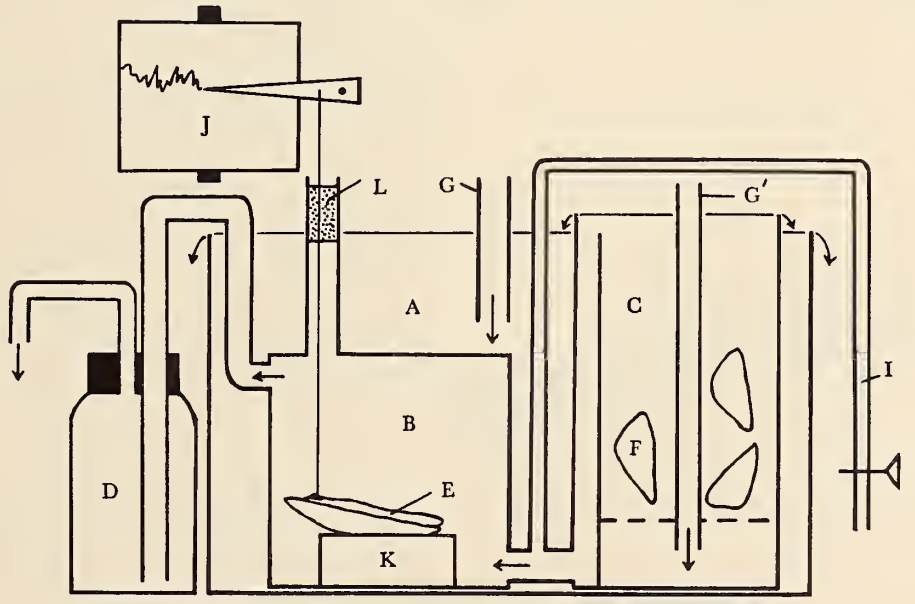

Figure 2

Apparatus used for the kymograph record of shell movement

A: water tank supplied with running sea water; B: metabolism jar; C: supply tank; D: water sample tank; E: pearl oyster; F: *Mytilus edulis*; G, G': supply tube; H: stop cock; I, I': tube for taking samples of water J: kymograph; K: stone sinker; L: liquid paraffin

Table 1

Relation between the rate of oxygen uptake of the pearl oysters and the oxygen content of the environment

Oxygen content (cc/L)	Oxygen uptake (cc/g dry tissue /hr)					
	A	B	C	D	E	Average
5.00 – 4.51	0.541	0.485	0.455	0.401	0.505	0.4774
4.50 – 4.01	0.537	0.499	0.445	0.379	0.488	0.4696
4.00 – 3.51	0.514	—	0.457	0.415	0.519	0.4762
3.50 – 3.01	0.526	0.495	0.450	0.375	—	0.4615
3.00 – 2.51	0.526	0.450	0.499	0.369	0.499	0.4586
2.50 – 2.01	0.491	0.451	—	0.419	—	0.4537
2.00 – 1.51	0.491	0.405	0.445	0.315	0.432	0.4176
1.50 – 1.01	0.298	0.098	0.279	0.086	0.217	0.1956
1.00 – 0.51	—	0.023	0.032	0.066	0.115	0.0590
0.50 – 0.15	—	0.011	0.014	0.024	0.009	0.0145

Date of experiment: October 22 to November 9, 1965
Cl: 18.01 to 18.45‰

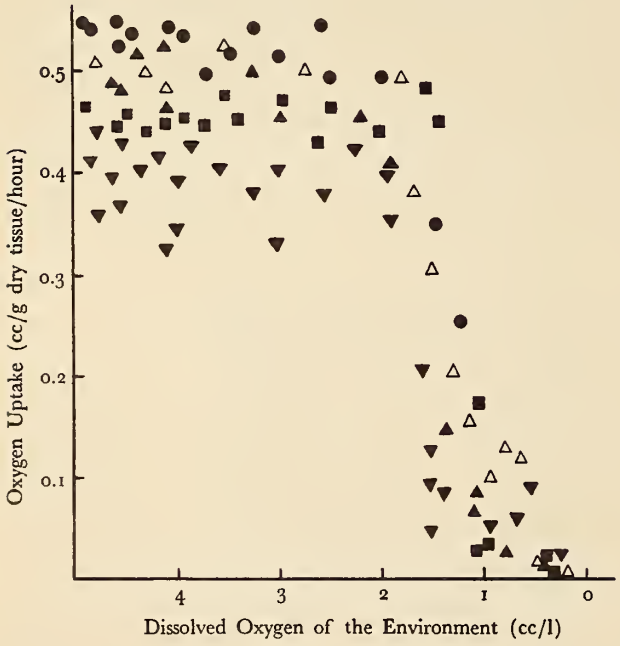

Figure 3

Effect of low oxygen content on the oxygen uptake rate of the pearl oysters

As shown in Table 1, the rate of oxygen uptake was 0.372 - 0.541 cc per g dry tissue weight[1] per hour when the amount of oxygen of the sea water was above 1.5 cc per liter. Mori (1948 a) found it to be 0.029 - 0.068 cc per g wet tissue weight[1] per hour; Mori (1948 b), 0.02 - 0.05 cc per g wet weight per hour; Sawano (1950), 0.074 to 0.1447 cc per g wet weight per hour; Uemoto *et al.* (1964), 0.022 - 0.087 cc per g wet weight per hour; Miyauti & Irie (1966 b), 0.3 - 0.6 cc per g dry weight per hour. These differences in value of the rate of oxygen uptake may be due to differences in experimental conditions, such as water temperature, age of oysters, experimental season, physiological condition of oysters and other parameters.

Berkeley (1923) reports that the presence of the crystalline style in certain molluses is related to anaerobic respiration. He observed that a mollusc maintained under anaerobic condition for 8 days lost the crystalline style entirely. On the other hand, Nozawa (1929) found that the crystalline styles of *Ostrea circumpicta* disappear after anaerobic respiration, though not completely. In this experiment, the crystalline style diminished in size after 48 hours (but did not disappear entirely), under 0.5 cc oxygen content per liter of sea water.

Shell Movement: A representative kymograph record of shell movement under normal conditions during this experimental period is shown in Figure 4. Figure 5 shows shell movement at different levels of oxygen content. The results were obtained from 4 oysters.

Under normal conditions, the degree of valve opening showed periodic changes (daily rhythm), and the frequency of opening and closing was relatively low (Figure 4). If, however, the oxygen content was reduced to about 1.5 cc per liter, the frequency of opening and closing was much higher, and the degree of valve opening was greater. When the oxygen content was reduced to about 0.5 cc or less per liter, the daily rhythm of shell movement disappeared.

All oysters gradually regained their normal vitality when they were returned to a pearl farm after 3 to 7 days' experiments.

DISCUSSION

The present experiments show that the rate of oxygen uptake and shell movement of the Japanese pearl oyster are independent of the oxygen content of the environment, when the latter is above 1.5 cc per liter.

It has been known that low oxygen content of the environment influences the physiological activity of the Japanese pearl oyster. According to Sawano (1950) and

[1] 10 g wet tissue weight without shell is equivalent to about 1.2 to 1.3 g dry tissue weight without shell.

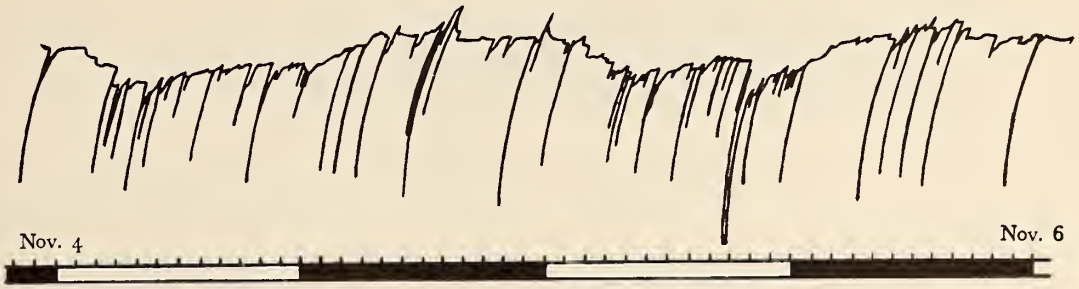

Figure 4

Kymograph record showing the shell movement of pearl oyster in normal sea water

White and black bands at the bottom show daytime (6:00 – 18:00) and night time (18:00 – 6:00). The writing pen is at the lowermost position when shell is closed.

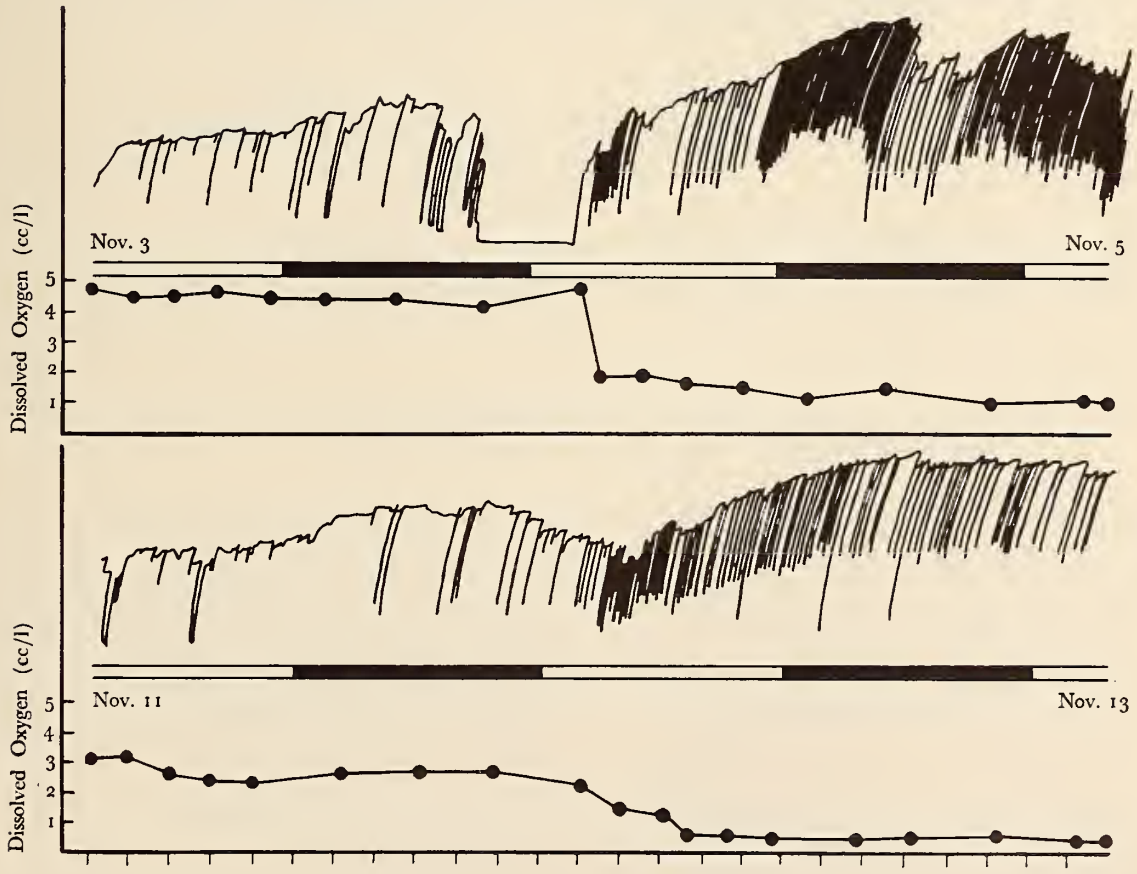

Figure 5 – continued next page

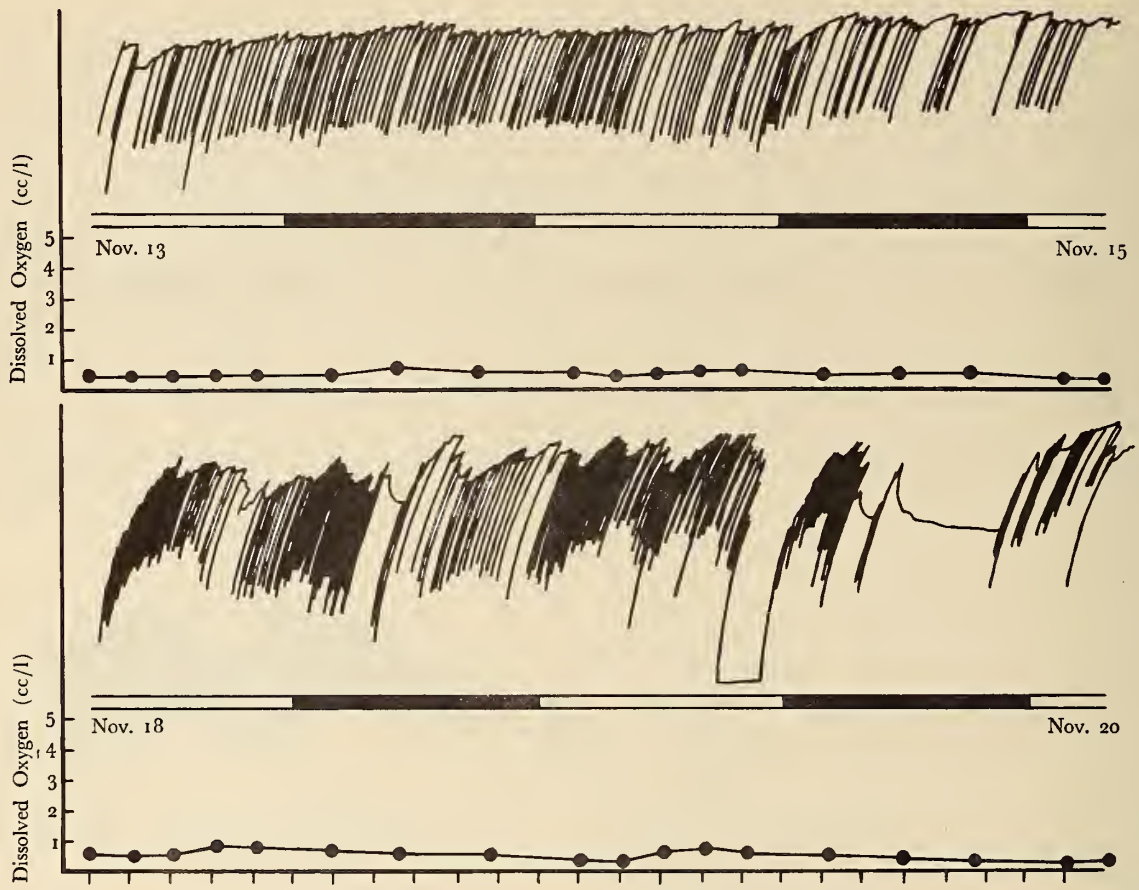

Figure 5

The effect of low oxygen content on the shell movement of the pearl oysters. The base line is marked in two-hour intervals.

Uemoto *et al.* (1964), the rate of oxygen uptake of the pearl oyster was almost directly proportional to the oxygen content of the sea water. On the other hand, Mori (1948b) and Miyauti & Irie (1966b) found that the rate stayed constant when the amount of oxygen of the sea water was above 0.5 cc per liter and 1.5 - 1.0 cc per liter, but it decreased considerably when the amount was lower than that level. The results of the former two studies differ from those of the present experiment; the latter are roughly similar to the present results. These differences in the rate of oxygen uptake may be due to differences in the experimental methods used. In the previous investigations, the water surface was covered with liquid paraffin. Consequently, the oxygen content was reduced continually as the oyster removed oxygen from the water. Therefore, the results of such experiments do not accurately represent oxygen uptake at one particular oxygen content level. The method used in the present experiment, however, removes this difficulty, and fairly consistent results were obtained. In addition, the results of the present experiment are in agreement with those found for *Ostrea circumpicta* (Nozawa, 1929), *O. edulis* (Galtsoff & Whipple, 1930), *Ostrea gigas* (Ishida, 1935), *Pecten grandies, P. irradians* (Van Dam, 1954), *Mytilus edulis* (Bruce, 1926; Rottiiauwe, 1958), and *Anodonta cygnea* (Hers, 1943).

Low oxygen content also affects shell movement. Miyauti & Irie (1966b) reported that when the oxygen content was reduced to 1.5 - 1.0 cc per liter or less, the frequency of shell movement was much higher and the

degree of opening of the valves was greater; when oxygen was reduced to 0.5 cc or less per liter, the degree of opening of the valves was slightly smaller; and when it was reduced to 0.2 cc or less per liter, the valves eventually gape open after closure for several ten-minute periods. The minor difference in shell movement between the above results and the present results may be ascribed to the use of a different method. In the previous investigation, the water surface was covered with liquid paraffin, so that the oysters may be affected by accumulated metabolites in addition to the low oxygen content.

The results of the present experiments do not necessarily indicate the response of the oyster as a whole animal. However, oxygen uptake and shell movement are important physiological factors controlling the vitality of the oyster; therefore these results will offer some fundamental data for the living conditions of oysters and will give an indication of the tolerance to low oxygen tension.

The most reasonable conclusion is that the pearl oysters are affected by low oxygen content only when the latter is 1.5 cc per liter, or less.

SUMMARY

1. The effects of oxygen content on oxygen uptake and shell movement of the Japanese pearl oyster were studied.
2. The rate of oxygen uptake of this animal remained relatively constant until the oxygen content of the medium was decreased to 1.5 cc per liter.
3. The shell movement was generally normal until the oxygen content of the medium was decreased to 1.5 cc per liter.
4. Below 1.5 cc per liter, the rate of oxygen uptake dropped to a low level, and the shell movement was abnormal.

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